Atmospheric Dynamics of Two Eccentric Transiting Planets: GJ436b and HD17156b

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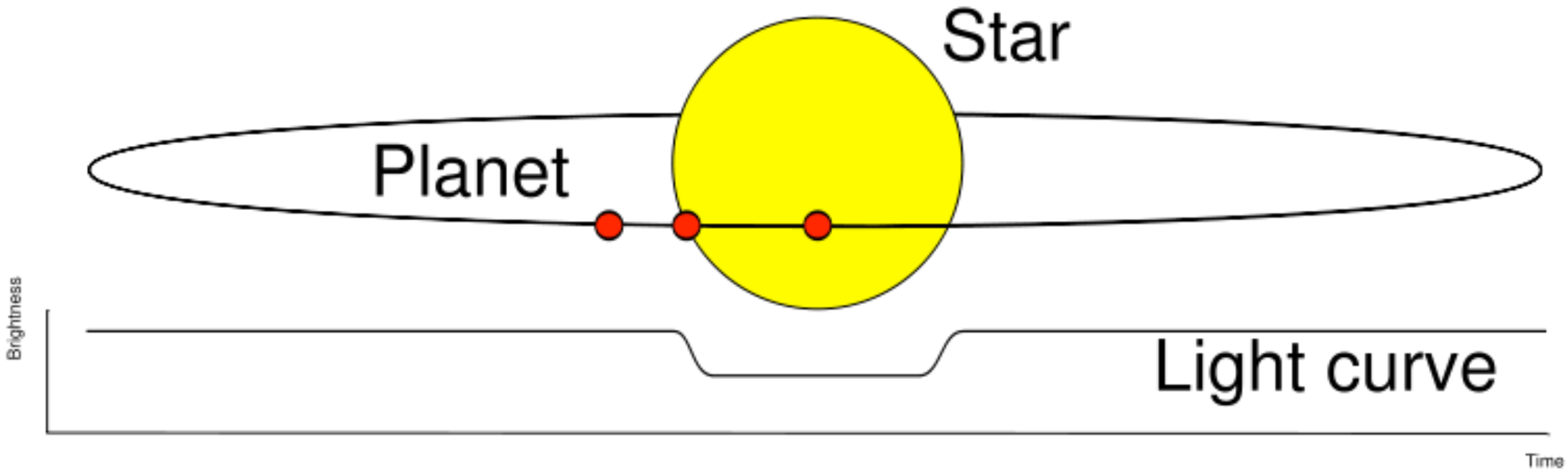
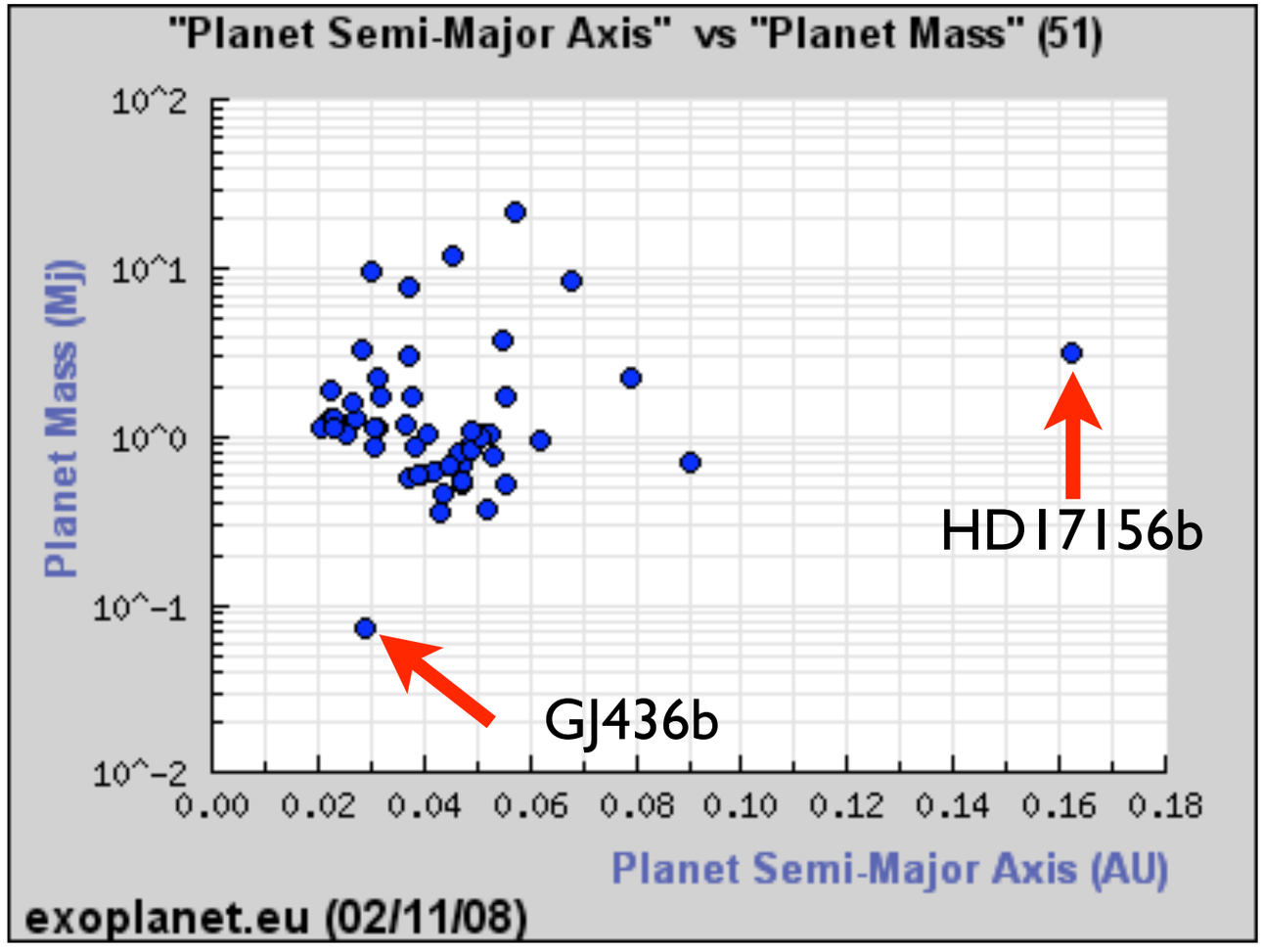
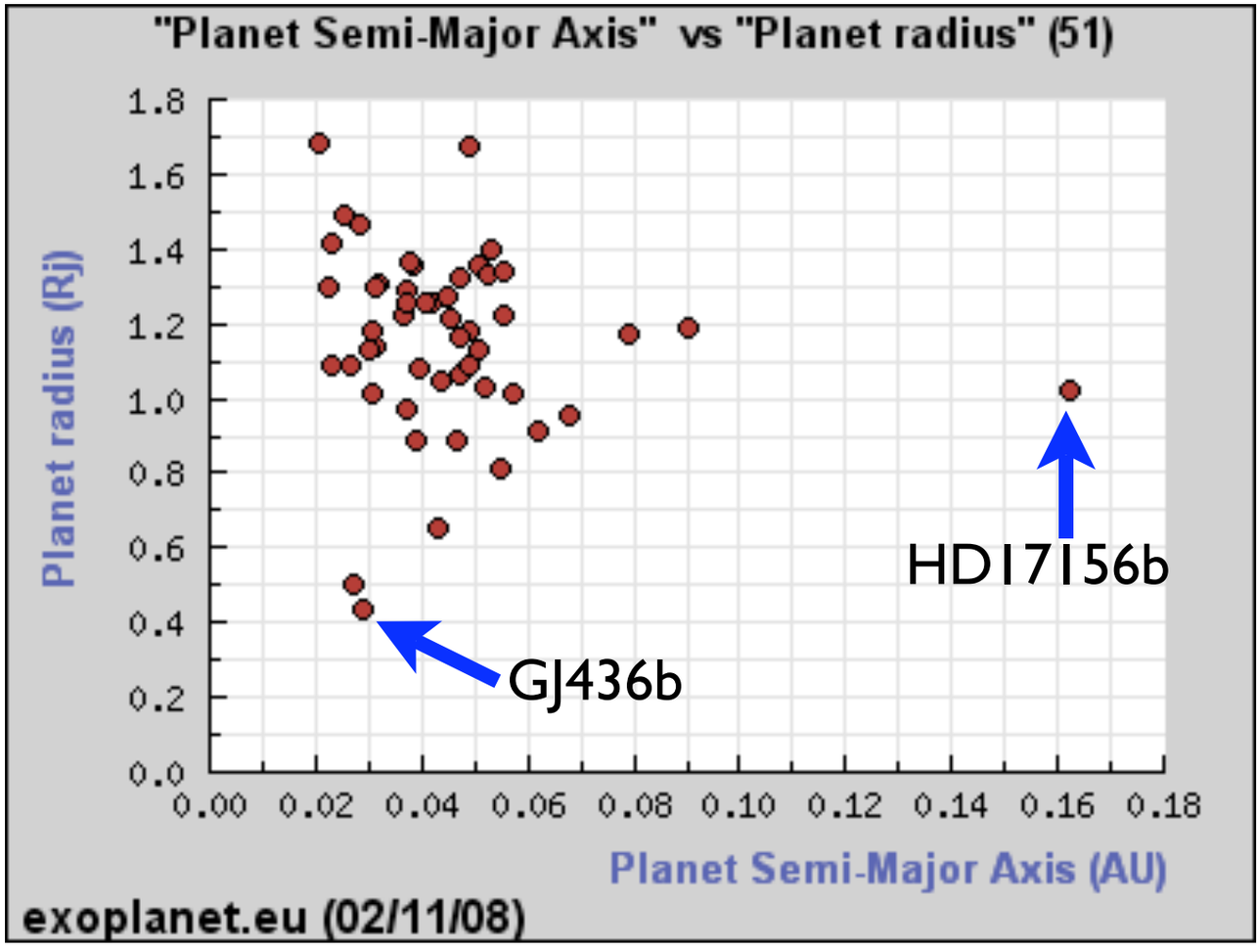
Motivation

- Studying weather on extrasolar planets can help us understand current observations
- Chance to test unusual atmospheric forcing regimes and broaden our understanding of atmospheric dynamics
- The goal of this study is to test the effects of eccentric orbits on the atmospheric dynamics of extrasolar planets

Transiting Extrasolar Planets







SPARC Model Atmosphere

(Substellar and Planetary Atmospheric Radiation and Circulation Model)

MITgcm

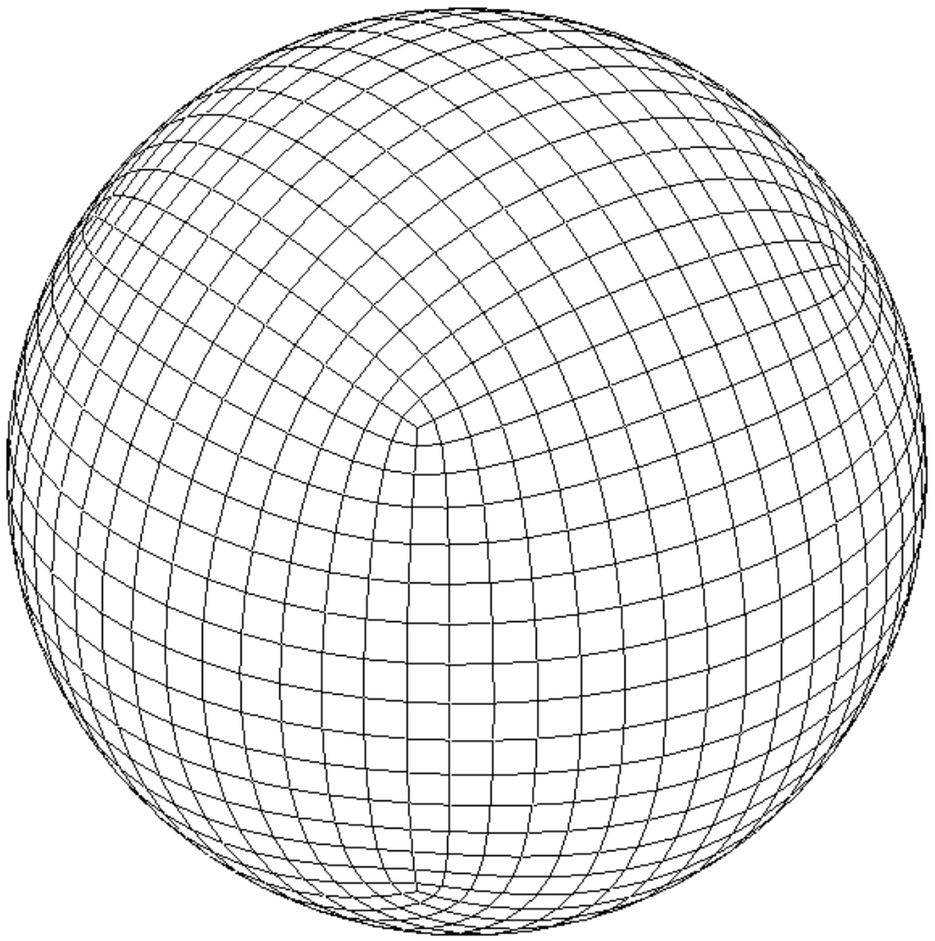
- Solves 3D primitive equations

$$\frac{d\mathbf{v}}{dt} = -\nabla\Phi - f\mathbf{k}\times\mathbf{v}$$

$$\frac{\partial\Phi}{\partial p} = -\frac{1}{\rho}$$

$$\nabla\cdot\mathbf{v} + \frac{\partial\omega}{\partial p} = 0$$

$$\frac{dT}{dt} = \frac{q}{c_p} + \frac{\omega}{\rho c_p}$$



Cubed-sphere grid

Radiative Transfer

- Based on Marley & McKay (1999) radiative transfer model
- Plane-parallel two-stream radiative transfer scheme
- Opacities determined using correlated-k method
- Heating (q) determined from the divergence of calculated wavelength-dependent radiative fluxes

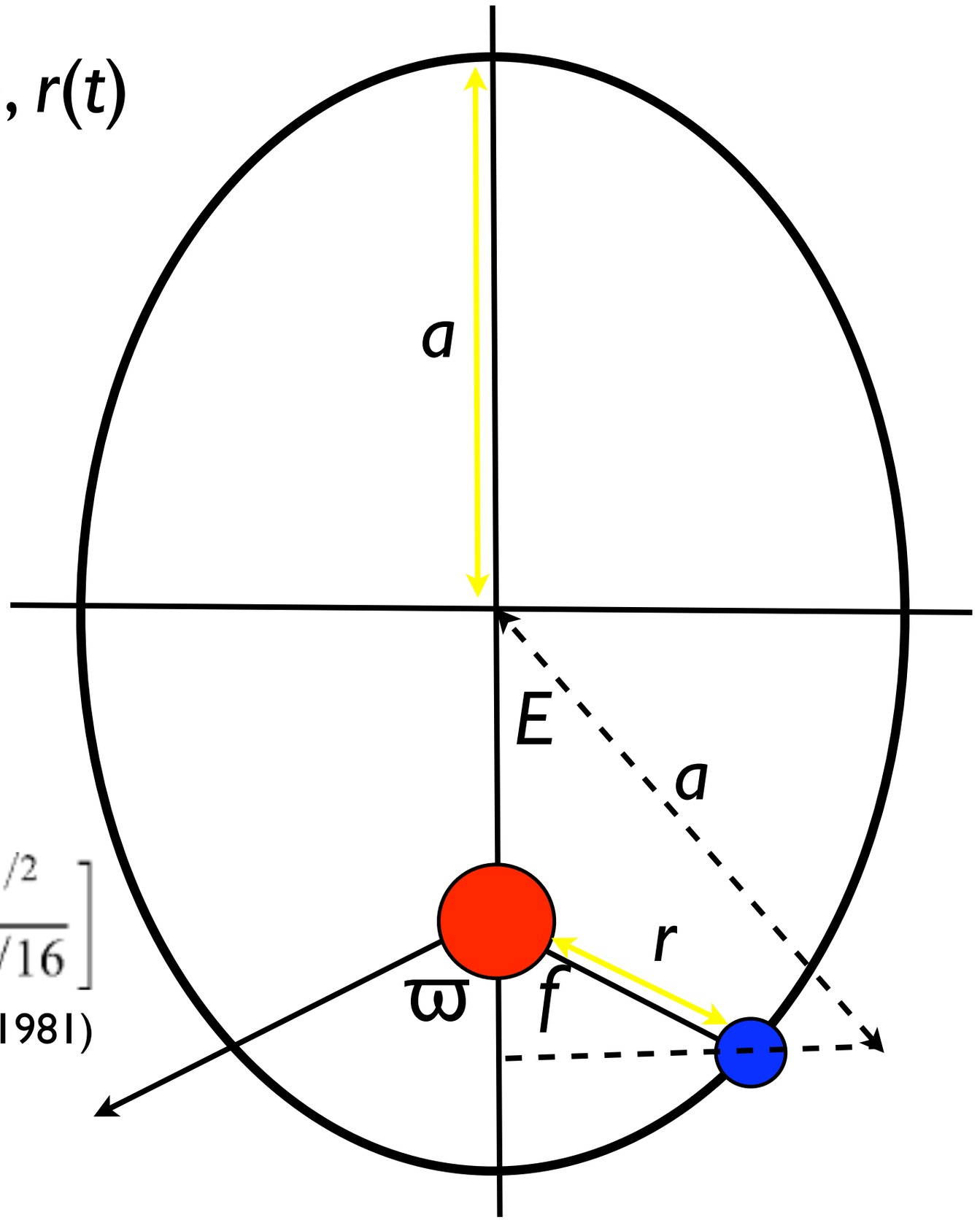
Eccentric Exoplanet Considerations

- Distance varies with time, *r*(*t*)

$$r(t) = a(1 - e\cos E(t))$$

$$M(t) = E(t) - e\sin E(t)$$

$$M(t) = n(t - \tau)$$



- Planetary rotation rate is likely non-synchronous

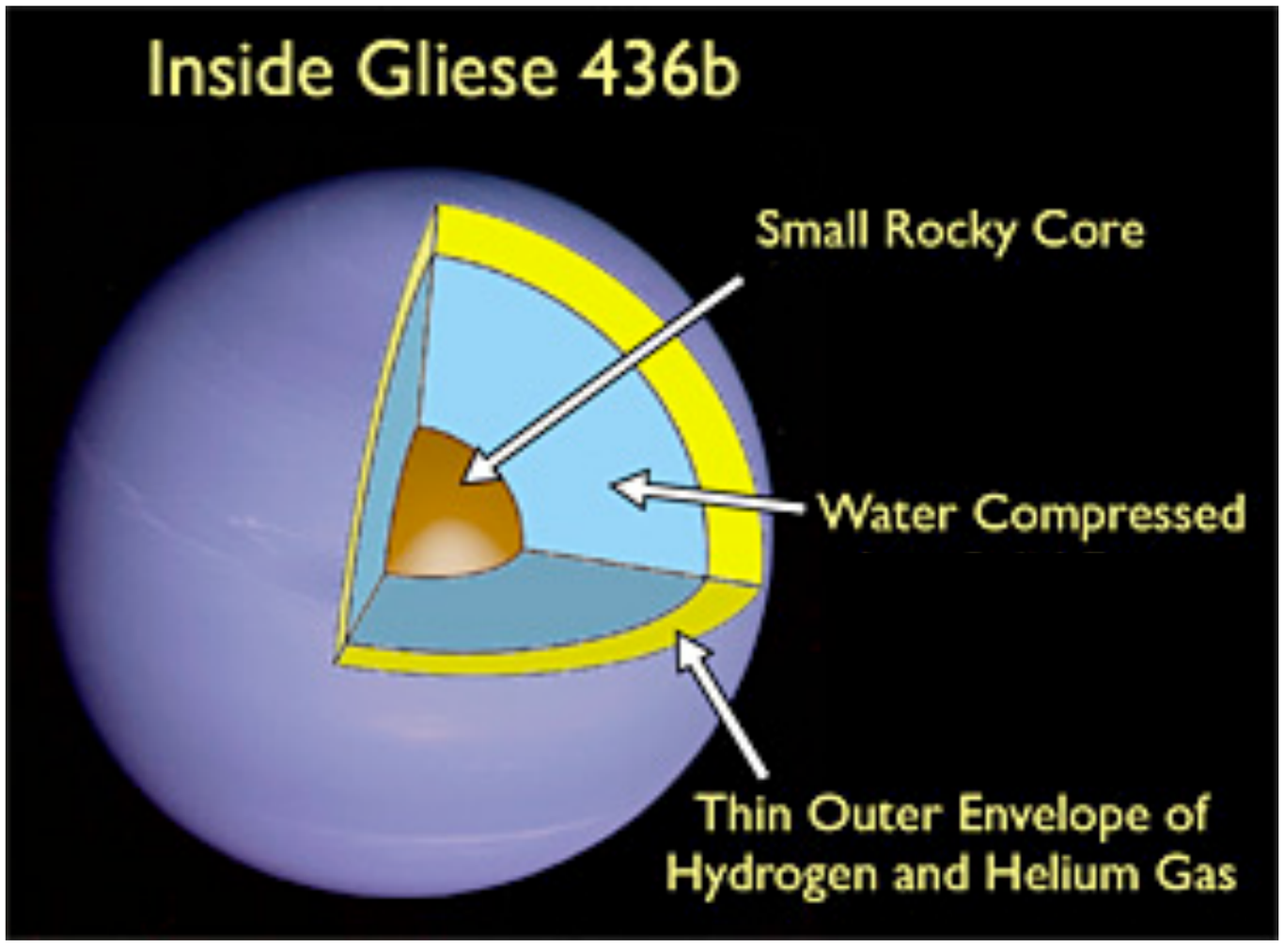
$$\tau_{\rm rot} = \tau_{\rm orb}\left[\frac{(1 + 3e^2 + 3e^4/8)(1 - e^2)^{3/2}}{1 + 15e^2/2 + 45e^4/8 + 5e^6/16}\right]$$

Hut (1981)

GJ436b: Hot Neptune

Planetary Parameters

- M_p = 0.071±0.006 M_J
- R_p = 0.437±0.035 R_J
- a = 0.028 AU
- e = 0.15
- g = 9.22 m/s^2
- P_{orb} = 2.643904 days
- P_{rot} = 2.328553 days

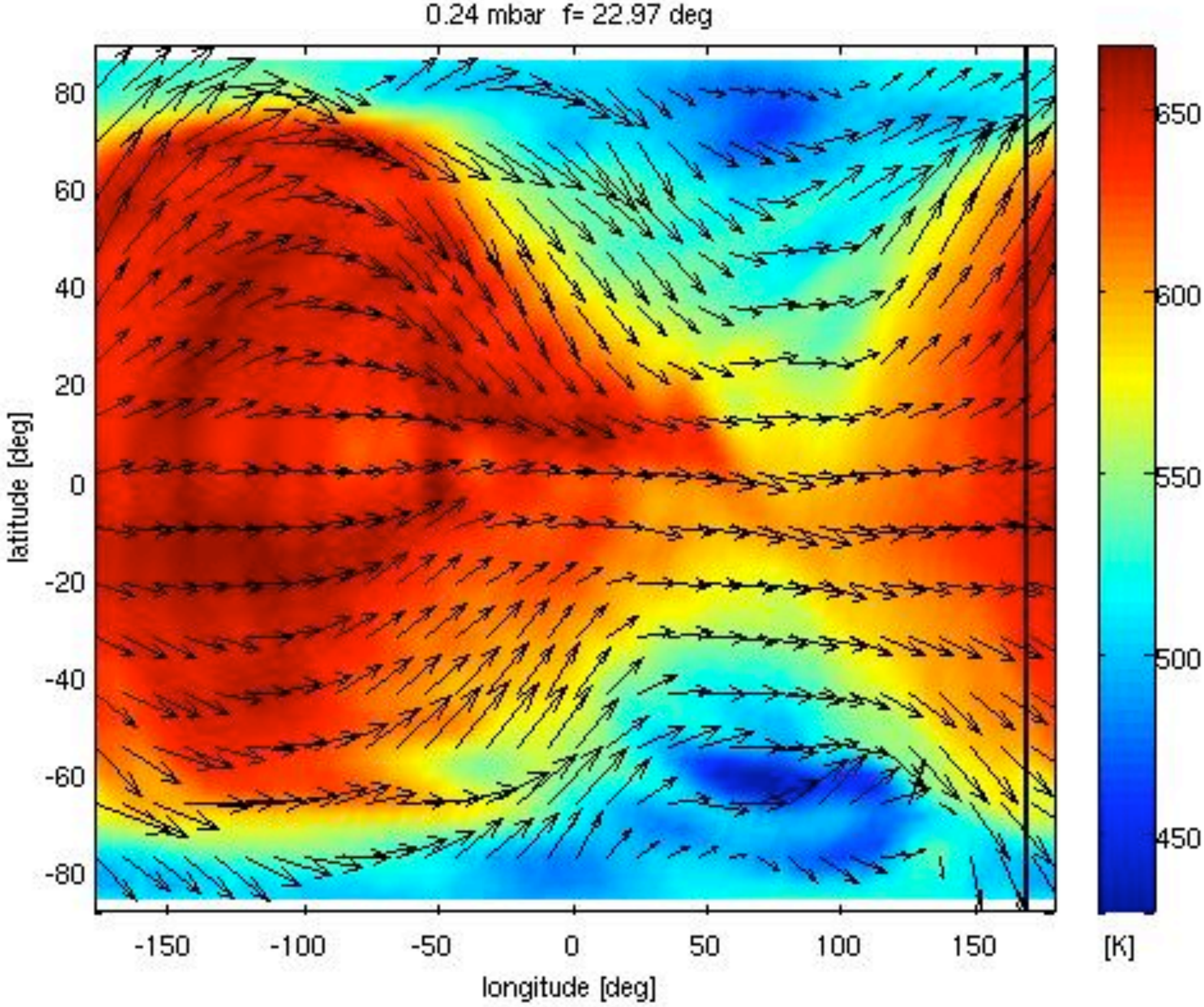


Credit: Jason Wright/UC Berkeley

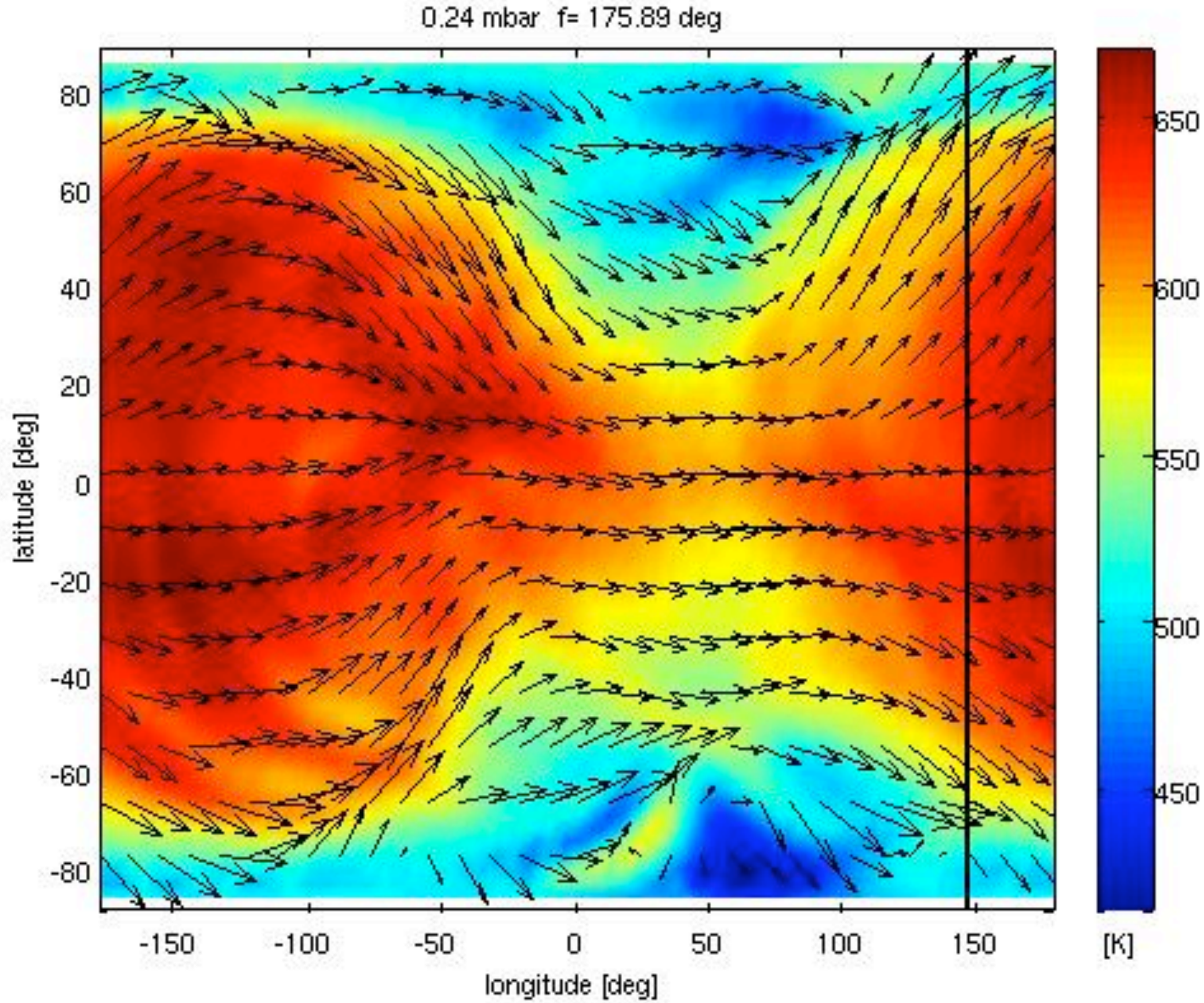
Stellar Parameters

- M2.5 (T_{eff} ~ 3200-3700 K)
- [Fe/H] < 0.0

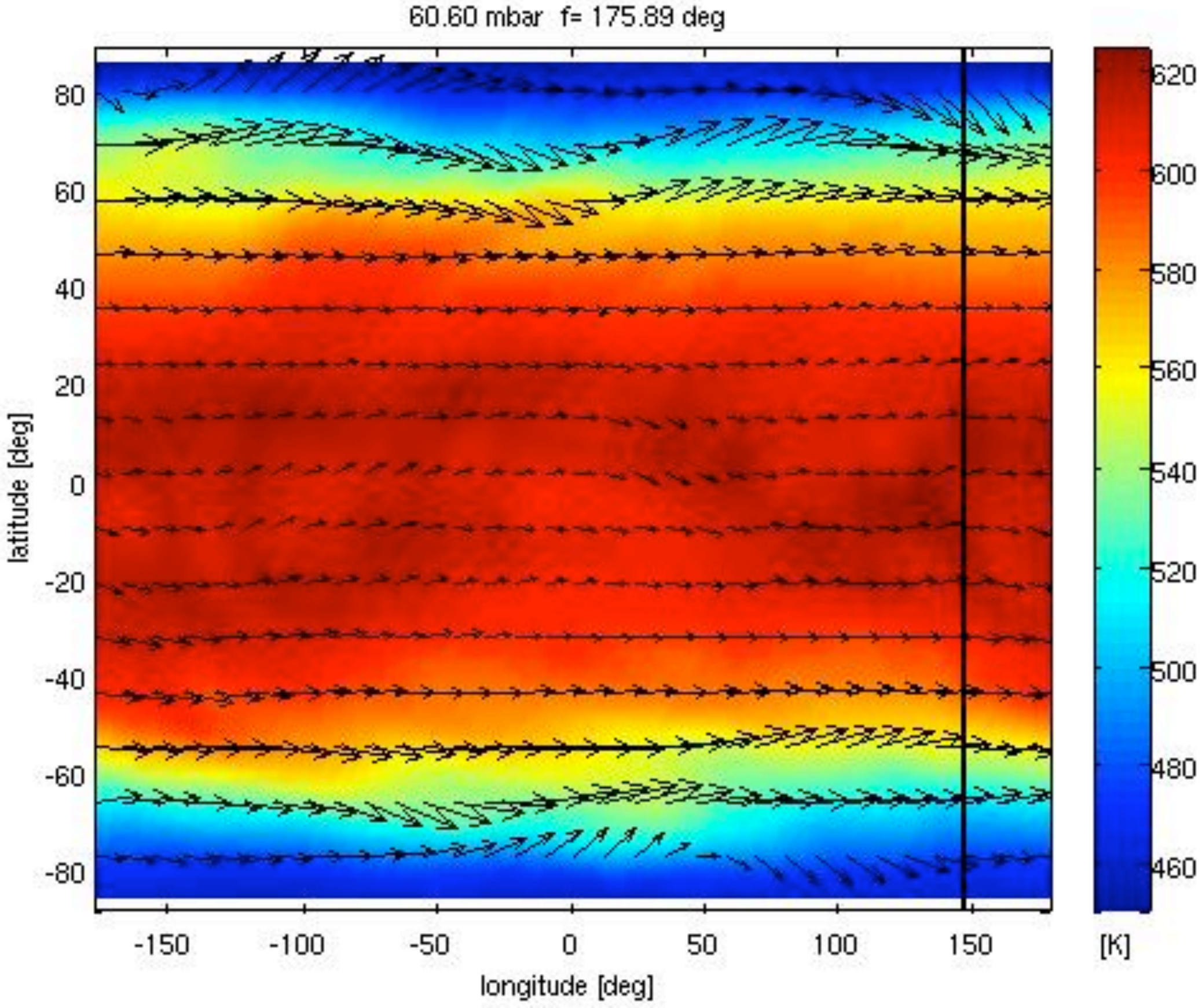
GJ436b 1x Solar



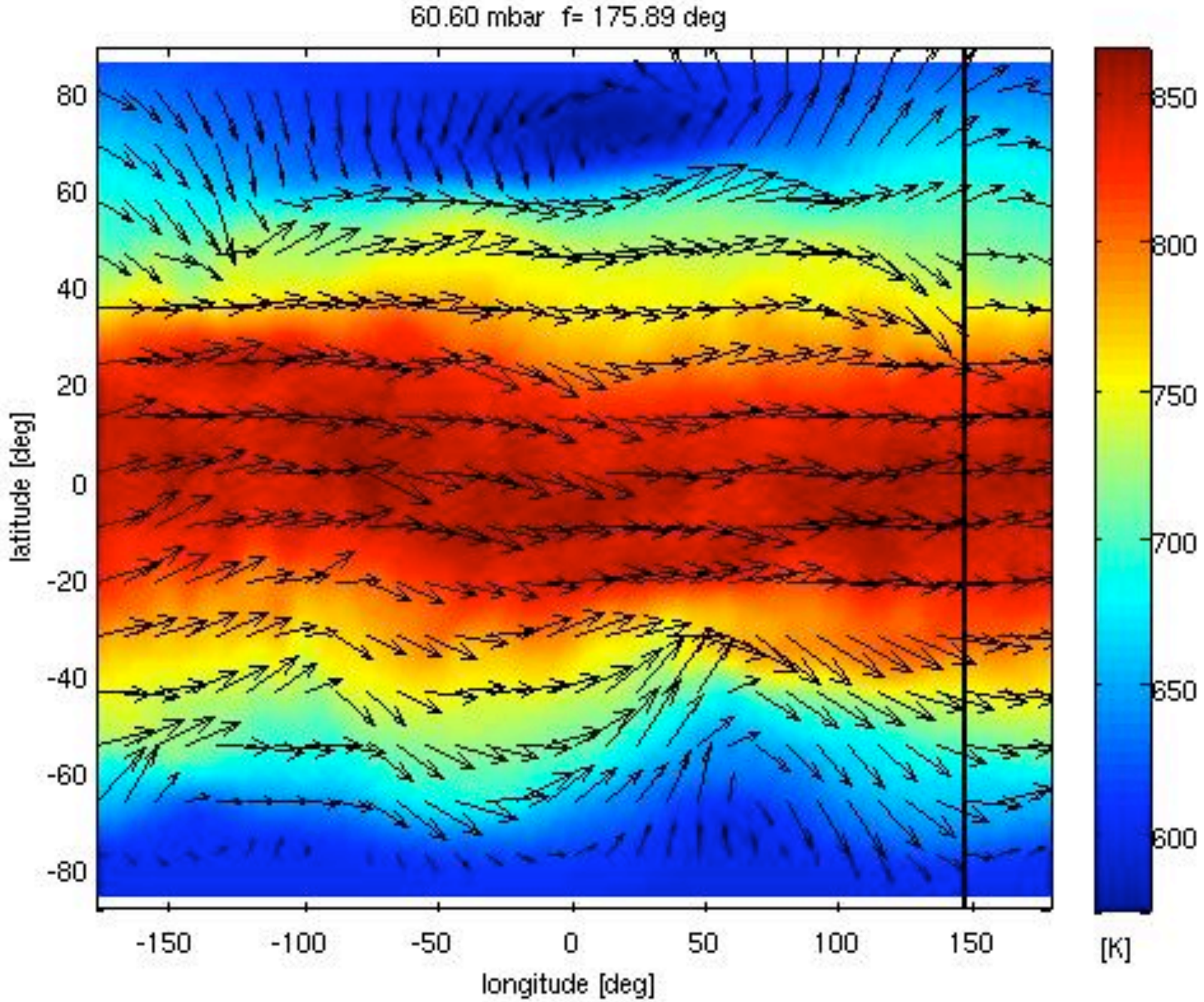
GJ436b 1x Solar



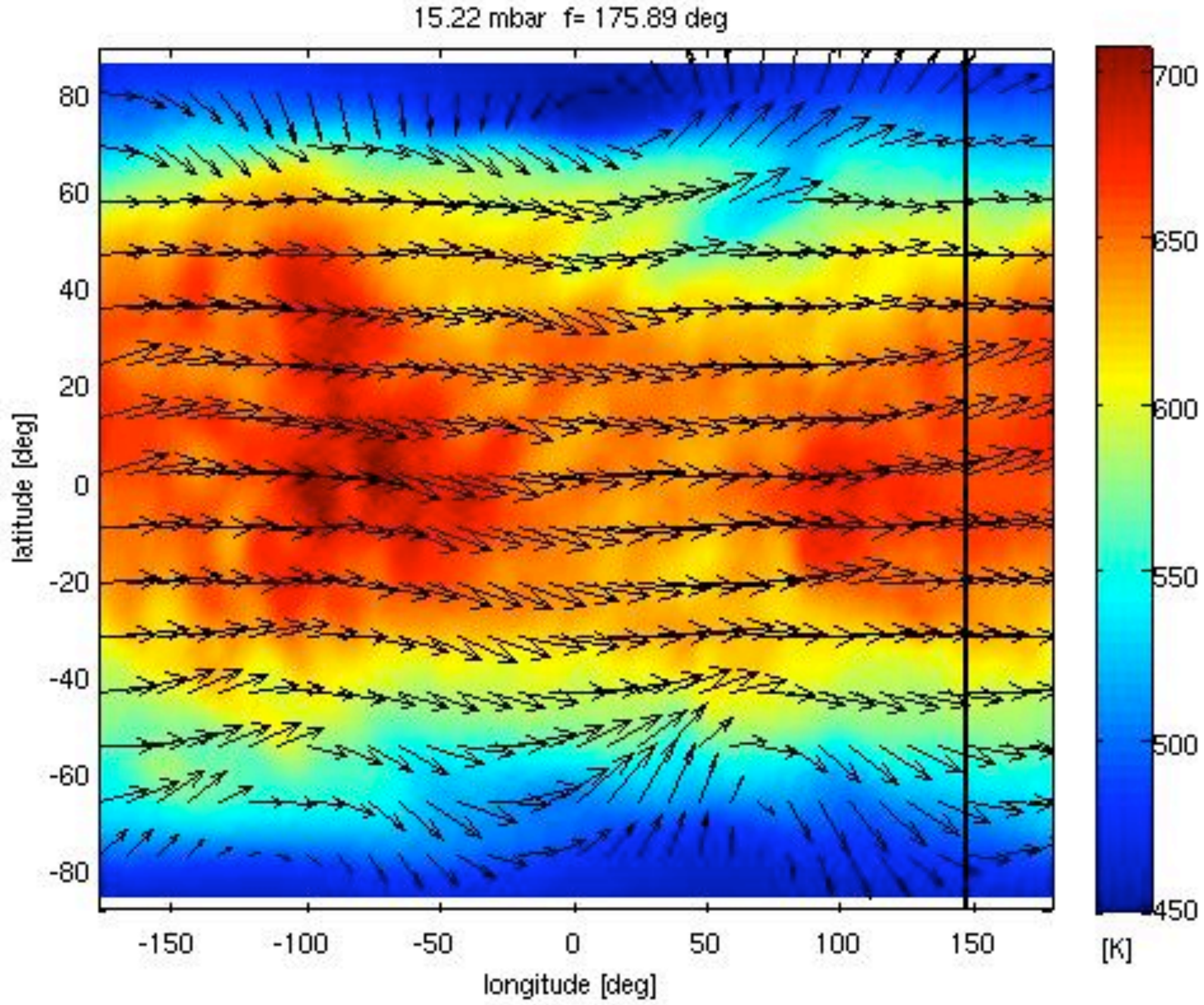
GJ436b 1x Solar



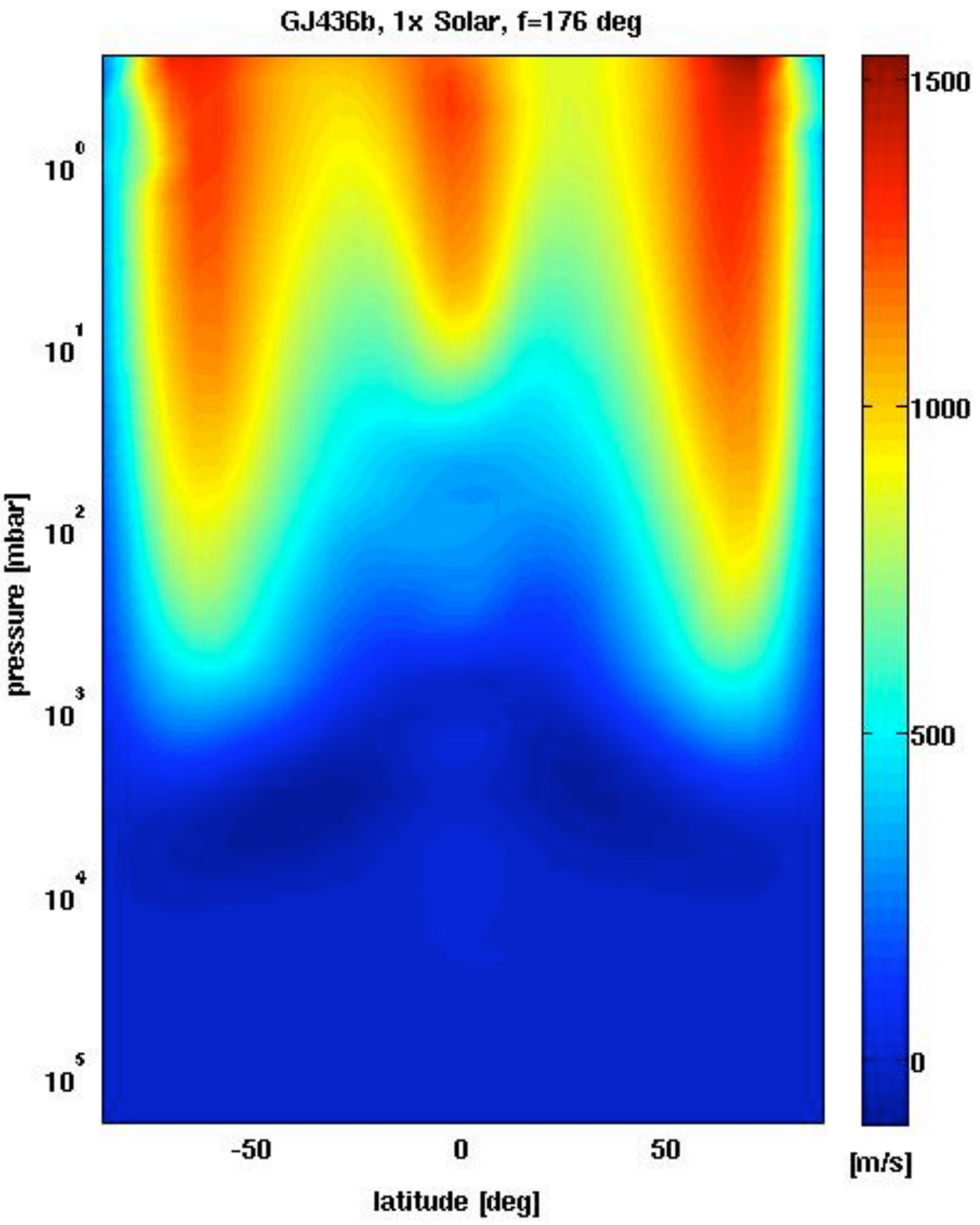
GJ436b 30x Solar

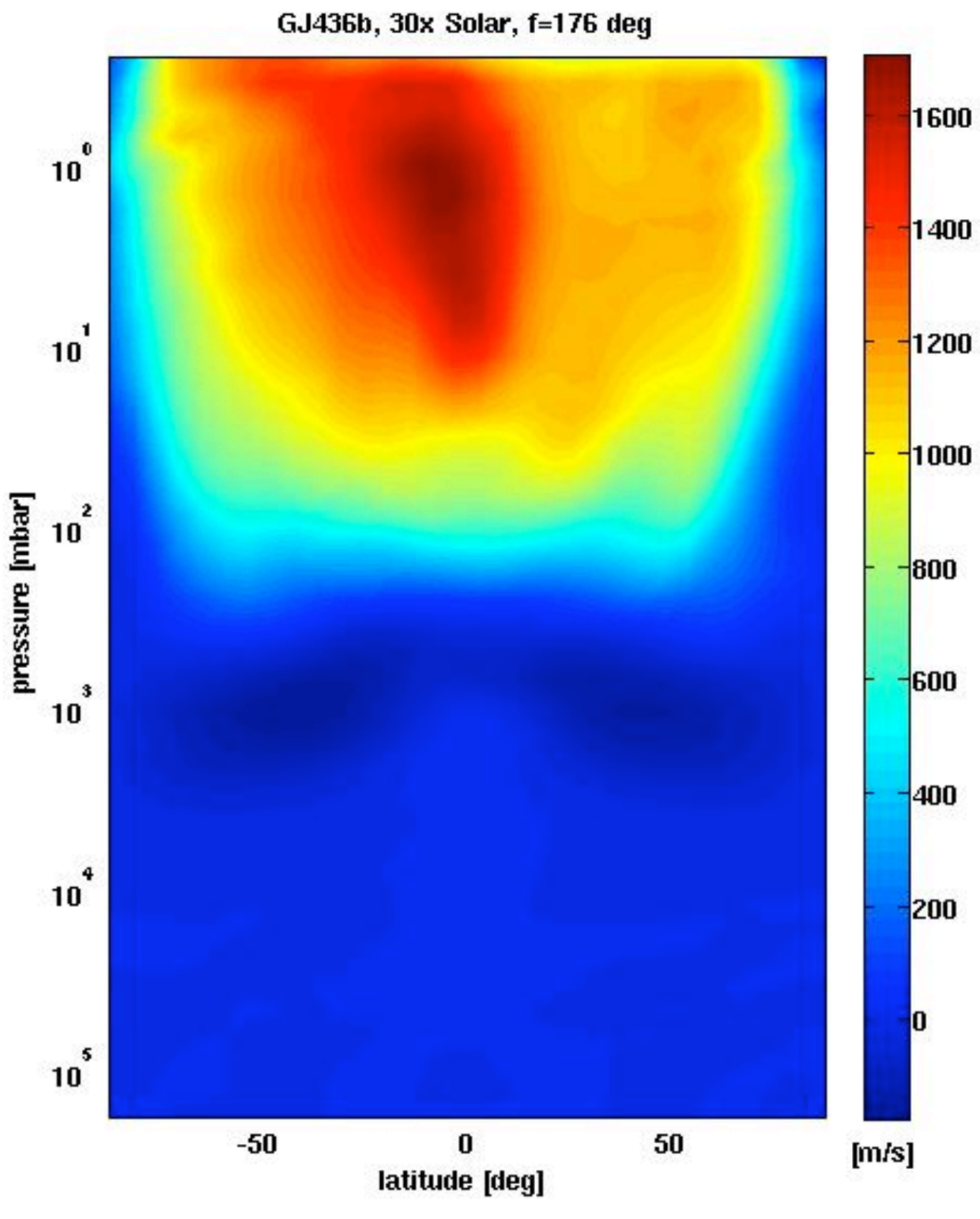


GJ436b 30x Solar



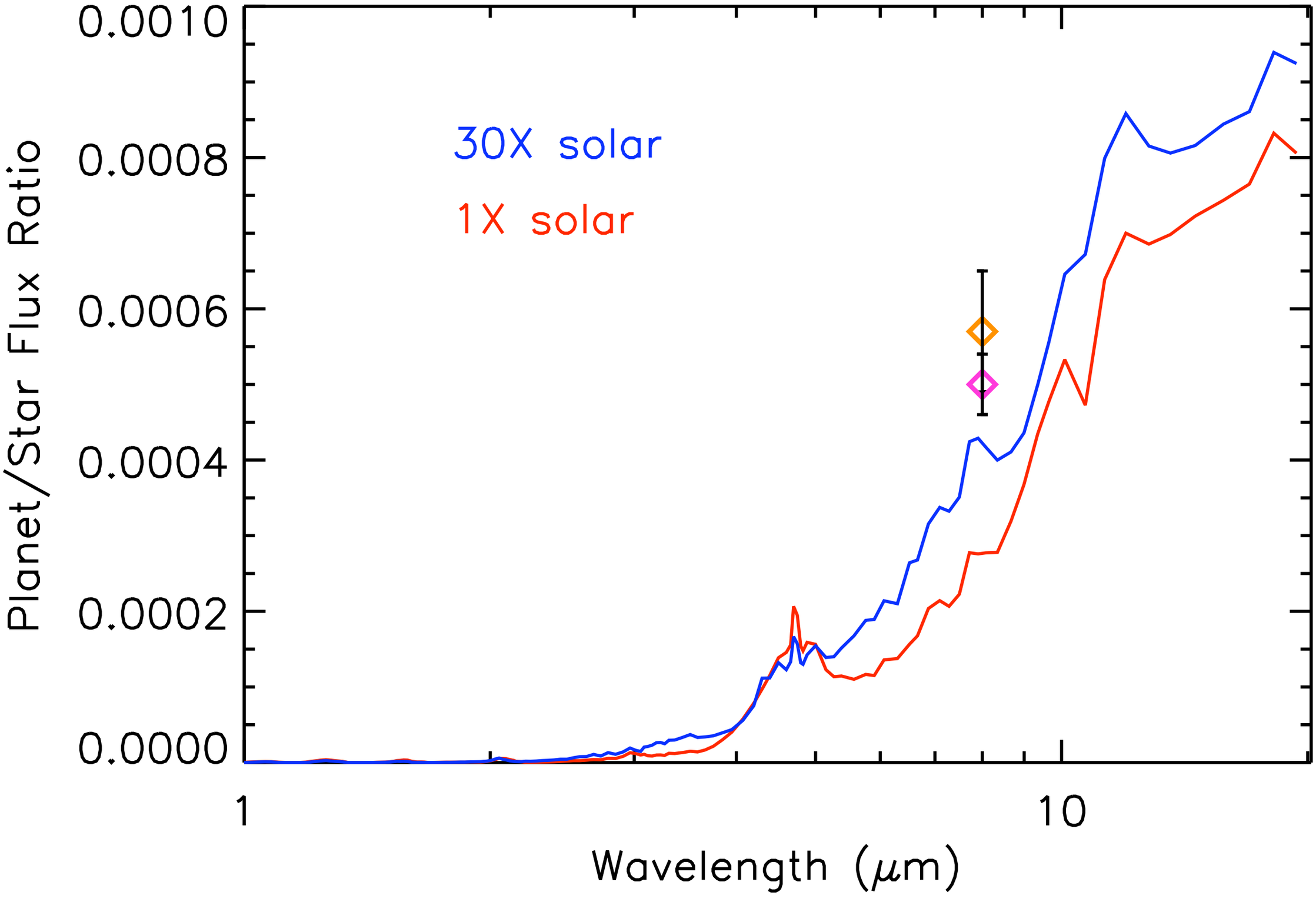
GJ436b Zonal Mean Zonal Winds





GJ436b 8 μm Observations

Secondary Eclipse



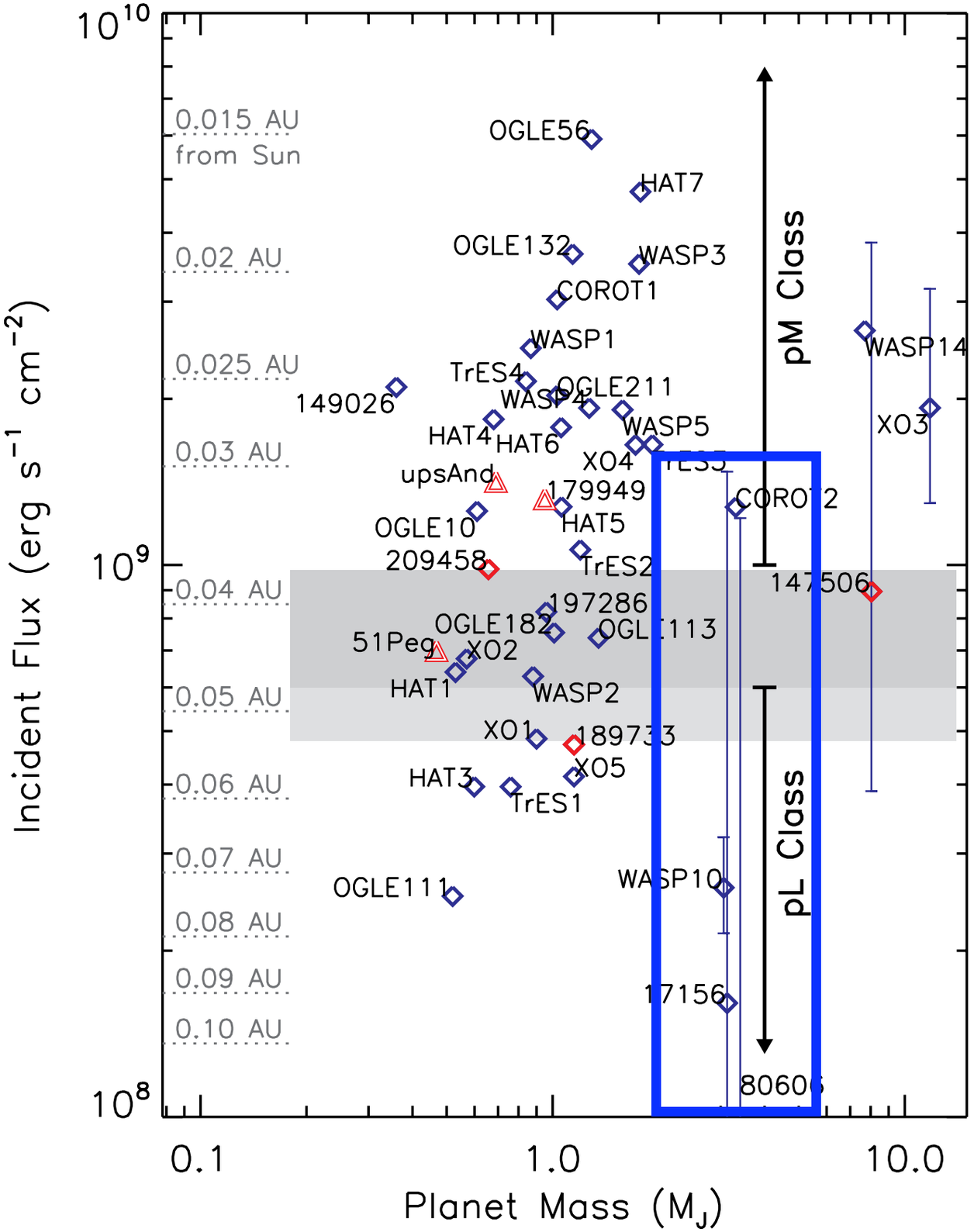
HD17156b: Eccentric Hot Jupiter

Planetary Parameters*

- M_p = 3.09 M_J
- R_p = 1.23 R_J
- a = 0.1589 AU
- e = 0.6719
- g = 50.6 m/s^2
- P_{orb} = 21.21747 days
- P_{rot} = 3.76797 days

Stellar Parameters

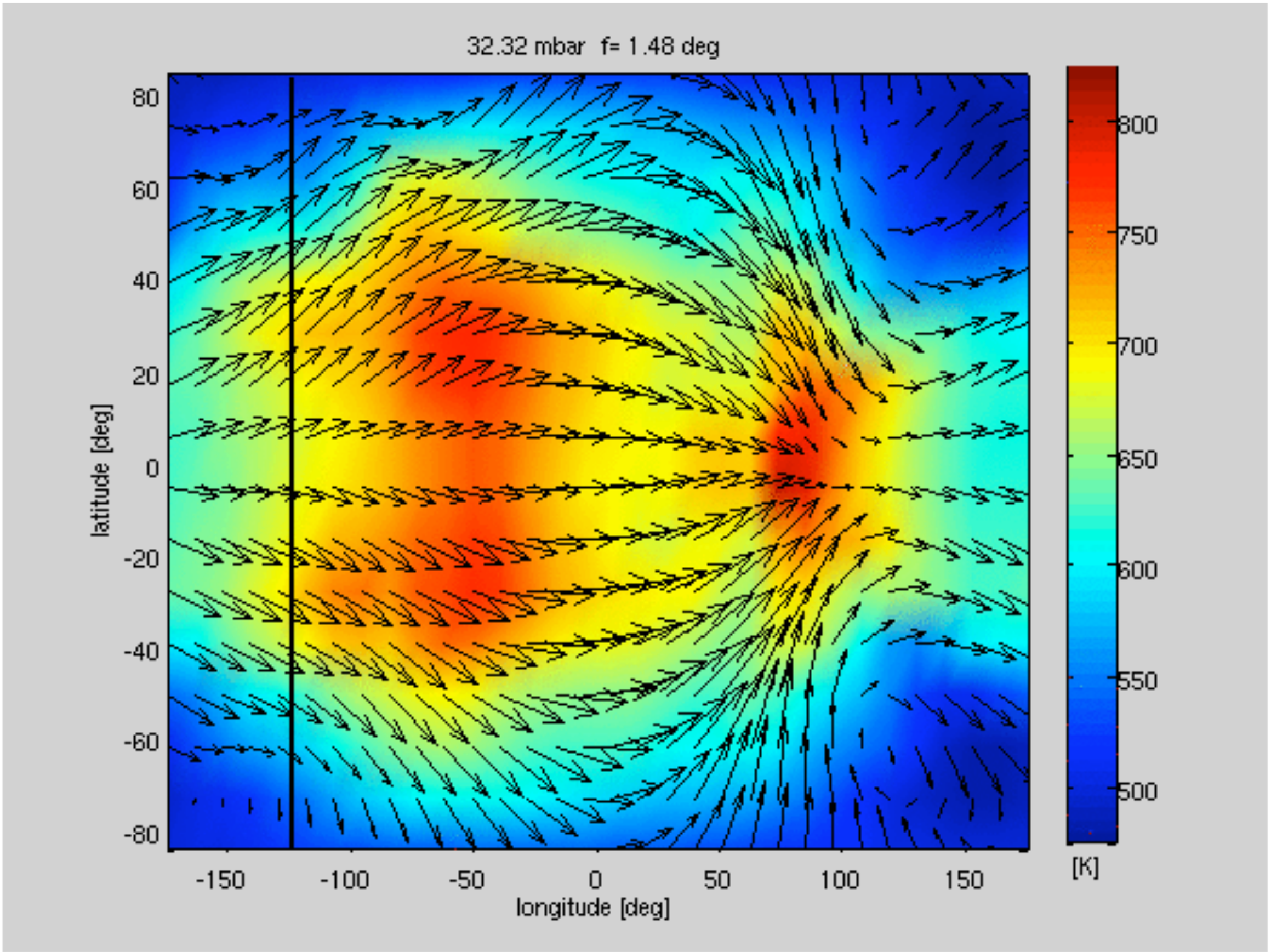
- G0 (T_{eff} ~ 6079 K)
- [Fe/H] = 0.24±0.05



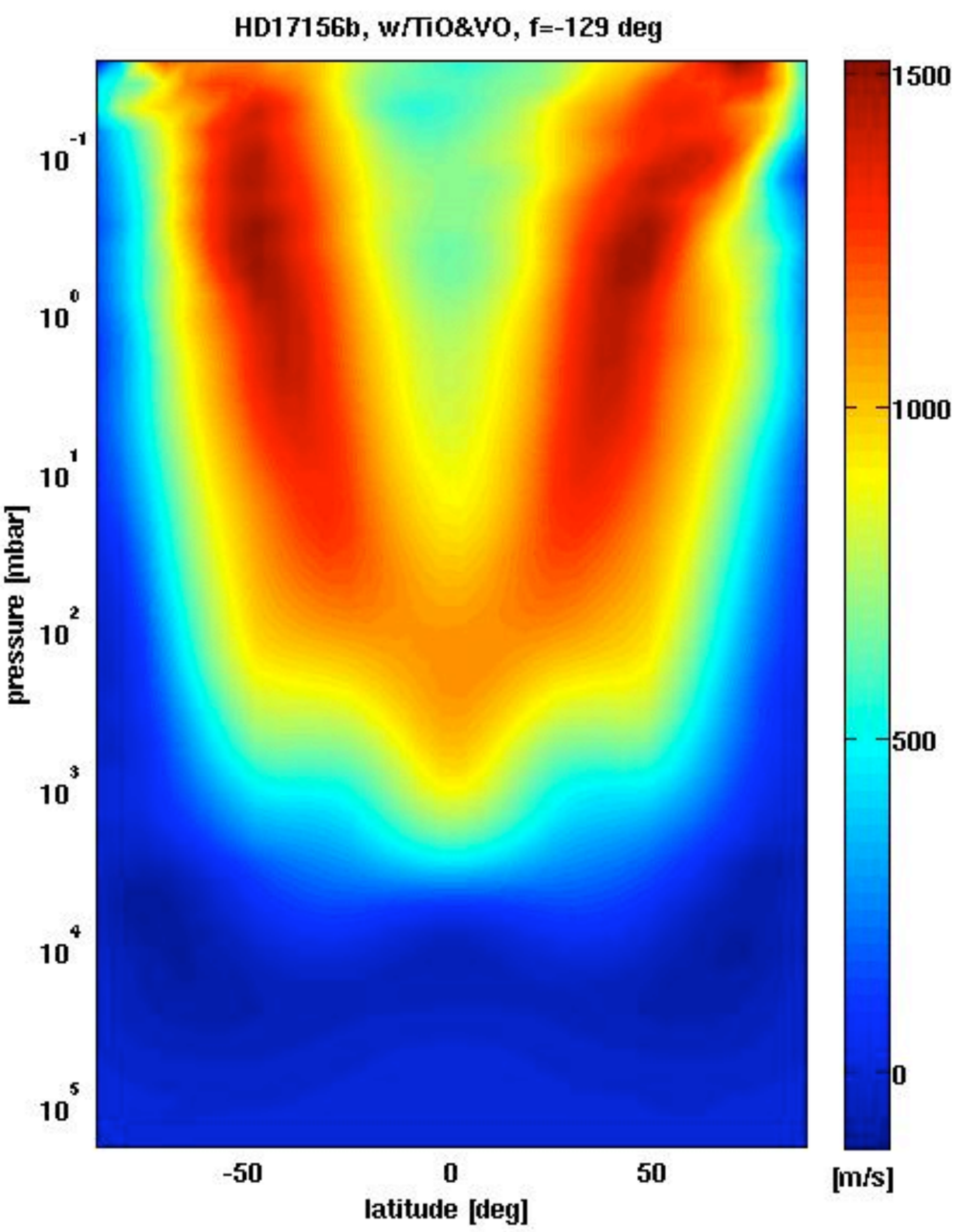
Fortney et al. (2008)

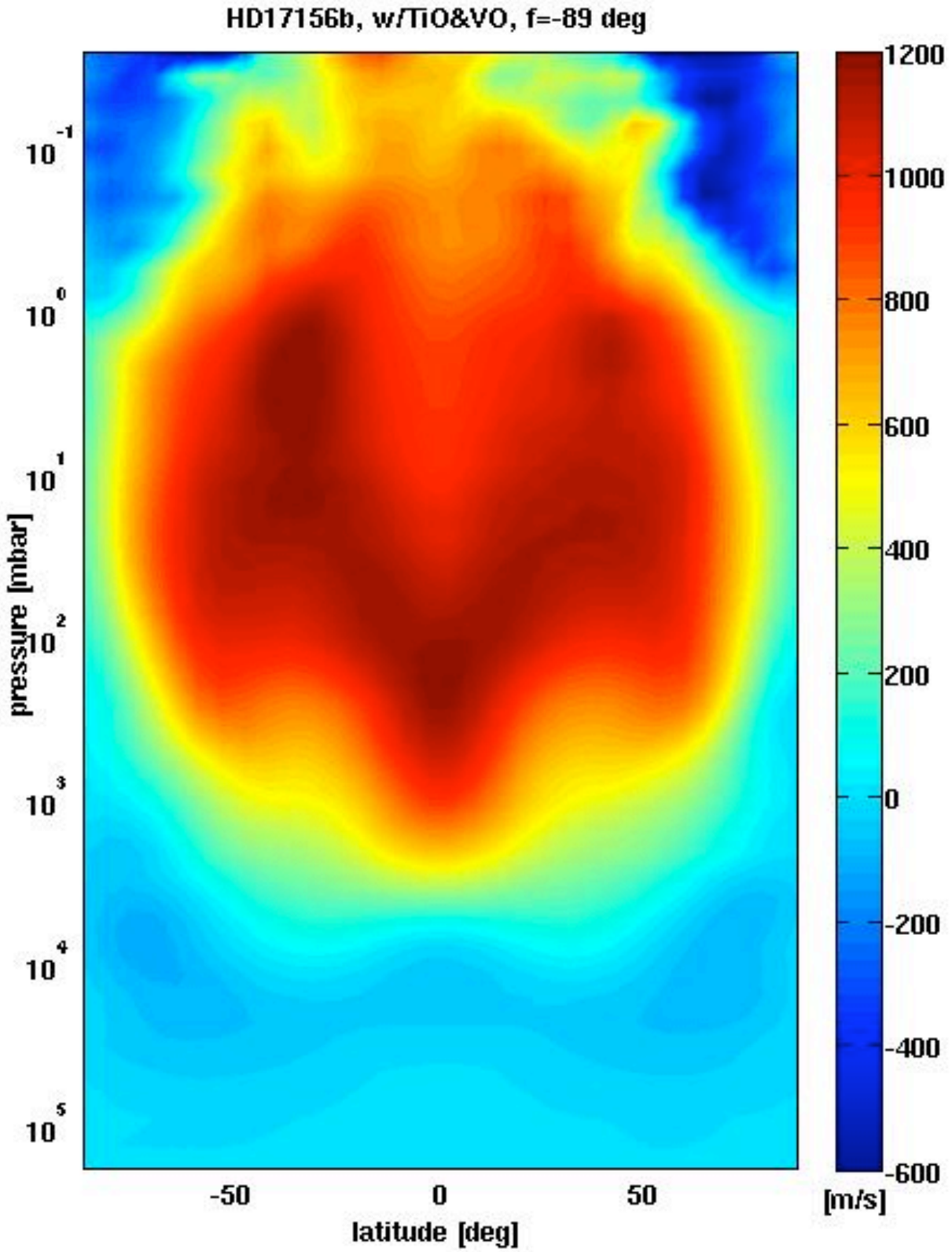
*Gillon et al. (2008)

HD17156b 1x Solar w/TiOVO, ~30 mbar



HD17156b 1x Solar w/TiOVO





Conclusions

- Non-synchronous rotation favors the development of mid to high latitude jets.
- Increasing chemical abundances in the atmosphere relative to solar tends to produce strong winds near the equator and increase temperatures near the level of the photosphere.
- Weather on eccentric planets will produce light curves that will be exhibit peak flux timing different from that of non-eccentric planets.

Future Work

- Explore the effects of tidal heating on atmospheric dynamics.
- Tackle the dynamics of other transiting extrasolar planets with *Spitzer* multi-wavelength data.

Questions?